Hydrometer test

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by

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Preface

This guide deals with determining of particle size in silt fraction.

The guide is part of a series, which explain the execution of geotechnical classification experiments as carried out at the Geotechnical Engineering Laboratory.

The guide is constructed as follows:

- *Appertaining standards*
- *Definitions*
- *Apparatus*
- *Equipment calibration*
- *Preparing the test sample*
- *Procedure for experiment*
- *Calculation*
- *Reporting*
- *Remarks*
- *Schema for experiment execution*
- *Appendix, if any*

It is recommended that the user of this guide reads the entire guide before the experiment is started.

Numbering of figures in the text is indicated by { }.

Units are indicated by [ ], e.g. [%].

Appertaining standard

The experiment is based on and further described in the standard DS/CEN ISO/TS 17892-4.

Definition

A hydrometer analysis is carried out in order to determine the weight-related distribution of soil grains after size in the silt fraction (2µm - 60µm).

The grain size is defined as the diameter of the ball that with the same density and in the same liquid has the same fall velocity as the particle.

The analysis operates on Stoke's law for balls as the soil sample in question is settled in a liquid.

Equation 1: Stoke's law.

$$v_s = \frac{1}{18} \cdot \frac{d^2 \cdot g \cdot (\rho_p - \rho_w)}{\mu}$$

v_s Velocity of the ball [m/s]

d Diameter of the ball [m]

g Gravitational constant [m/sec^2]

ρ_p Density of the particle [kg/m^3]

ρ_w Density of the water [kg/m^3]

μ Viscosity of the liquid [kg/(m*s)]

With Stoke's law, you can determine the diameter of the ball if you know the fall velocity v_s.

Apparatus

Apparatus for executing hydrometer experiment. The numbers refer to figure 1.

- Hydrometer {1}
- 1000 ml cylindrical glass {2}
- Thermometer, accuracy 0.5^{o}C {3}
- Peptisator fluid {4}
- Stop watch {5}
- Vibrating table
- Temperature regulated room
- Sieves 2 and 0.063 mm {6}
- Pressure sprayer {7}

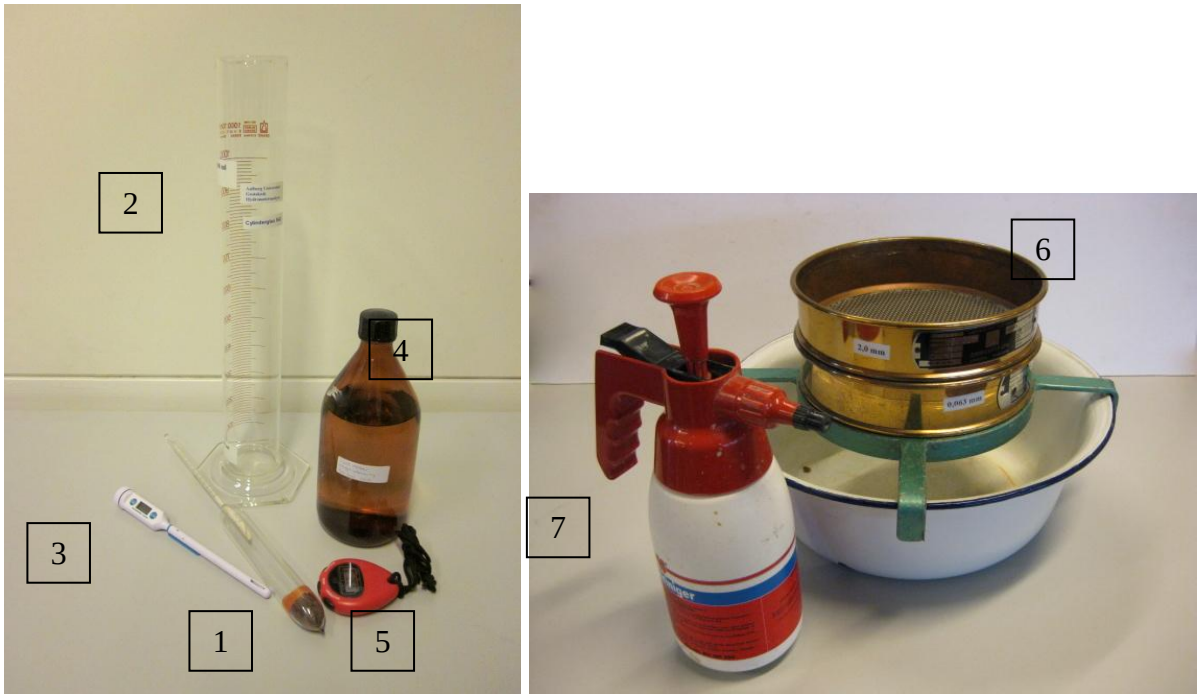

Figure 1: Apparatus for execution of hydrometer experiment. The numbers refer to the list above.

Equipment calibration

The hydrometers must be calibrated annually. No equipment needs to be calibrated prior to the experiment.

Preparation of test sample

Peptisator fluid

When the soil is settled, a peptisator is added to alter electrochemical elements of the soil particles and with this prevent the particles from clumping together.

The most favourable peptisator and the peptisator concentration for a given soil sort is determined as the peptisator, with which the sedimentation progresses the slowest.

Active peptisators are sodium pyrophosphate, sodium tripolyphosphate and sodium hexametaphosphate. The sodium hexametaphosphate is especially used as peptisator for particularly limy soil. For routine analyses, a 0.05 molar sodium pyrophosphate solution is used, which is made by dissolving 22.3 g $Na_4P_2O_7$, $10\mathrm{H}_2O$ in de-ionised water and filled up to 1 litre.

Test sample

The water content, w, is measured on a representative part of the sample.

For the hydrometer analysis of the sample, sample amounts as stated in table 1 are used. The amounts are indicative, and the amount used, W, is noted.

Table 1: Sample amounts depending on sample sort.

Soil sort	Amount
Soil containing sand	Up to 75 g
Cohesive soil with some sand	30 to 50 g
Plastic to very plastic soil	10 to 30 g

The measured sample, W, is placed in a waterproof container and 100 ml peptisator fluid is added. The container is closed firmly; tape the edge if necessary, and placed on the vibrating table at 170 RPM. The slurry is shaken thoroughly until all the soil is settled, approx. 4 hours, figure 2. With very plastic soil, it may be necessary to leave the slurry on the vibrating table overnight.

Figure 2: The slurry on the shaking table. The velocity of the shaking table must be set to 170 RPM.

The slurry is washed out on a 2 mm sieve under which a 0.063 mm sieve is placed over a dish.

- The slurry on the 2 mm sieve is sprayed with de-ionised water until the water running down on the 0.063 mm sieve is completely clear. Stirring lightly with a brush or spatula can be done.
- The part of the slurry that is now on the 0.063 mm sieve is washed out, figure 3, until the water running from here is completely clear.
    - The 0.063 mm sieve must not be pressed. If there is need for stirring the sample, this can be done lightly with a soft brush.
    - Tip the sieve from side to side if necessary. Make sure to collect all the washed out material.
- The samples collected on the 2 mm and 0.063 mm sieves are gathered and dried at 50^{o}C.
- The sample is weighed, W_{rest}, and fine sieving is carried out.
    - The screening material from the 0.063 mm sieve is weighed, $W_{0,063}$, and added to the washed out sample.

Figure 3: Washing out silt on a 0.063 mm sieve.

The slurry is considered washed out when the water running from the sieve is clear. At the most, 800 ml de-ionised water is used to wash out the slurry. If it is necessary to use more than 800 ml de-ionised water to ensure proper wash out and the collective volume of the wash out on the 0.063 mm sieve and thereby exceeding 1000 ml, the excess water must be removed by evaporation. Water must <u>not</u> be removed manually from the collecting tub because it risks removing particles from the slurry.

- The screenings from the 0.063 mm sieve is poured in a cylindrical glass; make sure to get all the material, figure 4.
    - It can be necessary to use the pressure sprayer to get the last of the slurry in the cylindrical glass. Make sure not to exceed a volume of 1000 ml.
- The cylindrical glass is put away for approx. 12 hours at a constant temperature. Use a room with mechanical temperature control.
- A reference cylindrical glass with 100 ml peptisator fluid and 900 ml de-ionised water are placed in the same location as the cylindrical glass with the slurry so that the two fluids will have the same temperature.
    - A cylindrical glass with pure de-ionised water is likewise made for rinsing the hydrometer.
- All cylindrical glasses are covered with film or plugged in order to prevent dust from gathering and fluid evaporation, figure 5.

Figure 4: The slurry is poured into a cylindrical glass. The pressure sprayer can be used to get the last of the slurry out into the cylindrical glass.

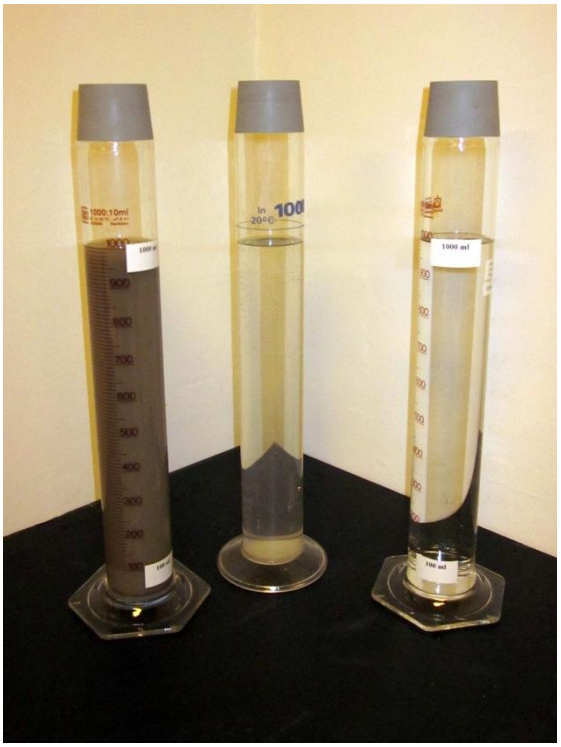

Figure 5: Cylindrical glasses in climate room. Each cylinder opening is plugged. The cylinders are filled with (from the left) slurry, de-ionised water and reference fluid.

Procedure for experiment

In order to determine the weight-related dry matter content in the slurry, a hydrometer with a scale indicating grams of soil per litre of slurry is used. For a particular reading on the hydrometer, the drop h can be calculated in advance with regard to the centre of gravity of repressed fluid volume.

As the hydrometer reading R'_h is done in a known time interval, the drop velocity, v_s, is found and the diameter of the ball, d, can be calculated.

So, the hydrometer reading indicates number of grams of soil per litre of slurry with a grain diameter of less than the calculated ball diameter.

Hydrometer experiment

Before the experiment is started, the hydrometer is placed in the reference cylindrical glass.

- A plug is put in the measuring glass.
- The slurry is shaken heavily until it is stirred up completely, figure 6.
    - It is important to ensure that there is no sediment in the cylindrical glass.

Figure 6: The cylindrical glass with the slurry is shaken before the experiment is started.

- The cylindrical glass is placed on a solid table and the stop watch is started immediately.
- Directly after the stop watch is started, the hydrometer is lowered gently into the slurry at floating depth, figure 7.
    - The slurry must be disturbed as little as possible when the hydrometer is being lowered into it.
    - The floating depth can be felt as this is where the hydrometer is stable in the water. If the hydrometer is let go too far from the floating depth, it will rock a long time in the slurry until it finds its stability.

Figure 7: The hydrometer is gently lowered into the slurry at floating depth.

- Hydrometer readings are taken, R'_h, at the times 15 sec., 30 sec., 1 min and 2 min. without removing the hydrometer from the slurry, figure 8. These four readings can be repeated until a consistent set of readings is achieved.
    - Hydrometer readings, R'_h, are taken on the top side of the meniscus as the opaqueness of the slurry makes it impossible to read on the bottom side of the meniscus.
- When the reading at 2 min. is done, the hydrometer is gently removed, and the temperature is measured.
- The hydrometer is rinsed in a cylindrical glass with de-ionised water by lowering it slowly into the glass with a rotating motion, figure 9. The hydrometer is dried off after each rinse.
- The hydrometer is placed carefully in the reference cylindrical glass and a reference reading is taken from this, R_0.
- The top and bottom side of the meniscus is read, and the size of the meniscus is found.
- The slurry is re-shaken after which the first reading is taken after 2 min.
- Further hydrometer and temperature readings are made after 4, 8, 30, 60, 120, 480 min and 24 hours. Between each reading, the hydrometer is carefully removed and rinsed in the cylindrical glass with de-ionised water.

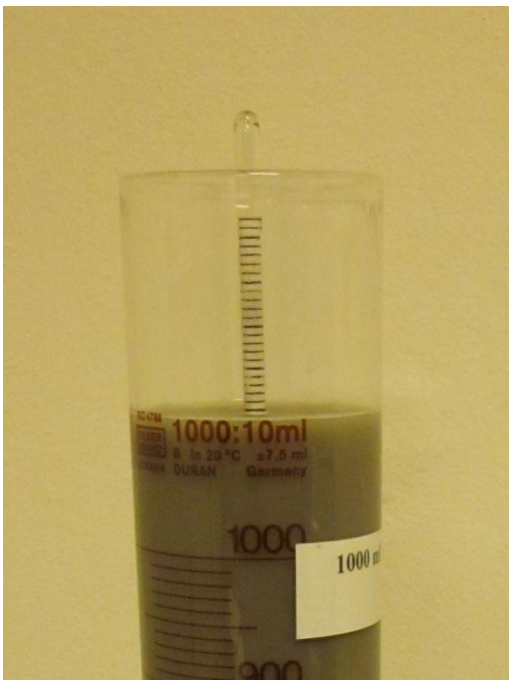

Figure 8: The hydrometer reading is done by the indexation on the stem of the hydrometer. The reading is done on the top side of the meniscus.

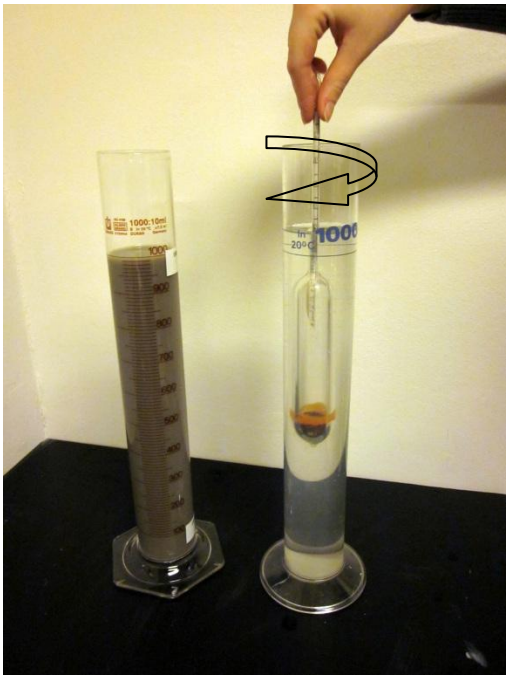

Figure 9: After each reading, the hydrometer is rinsed in de-ionised water. The hydrometer is lowered with a rotating motion so as to cast off any soil particles.

Before the hydrometer is put in the slurry, it is dried off thoroughly so that no water remains on it.

Directly before each reading, the hydrometer is carefully lowered into the slurry at floating depth so not to make turbulence. The hydrometer is lowered so it is able to stabilize itself in the slurry just before the reading.

The temperature in the slurry is read after each hydrometer reading. If the temperature deviates with more than 1°C from the temperature from the reference reading, a new reading of the reference cylindrical glass must be made.

Calculations

Calculation of sample size

The weight of dry matter in the slurry with a diameter of less than 0.063 mm is calculated with the help of knowing the water content, *w*.

$$W_S = \frac{W}{1+\frac{w}{100}} - W_{rest} + W_{0.063}$$

Correction of hydrometer readings R'_h

The hydrometer reading R'_h must be corrected for the meniscus as well as for the zero point inaccuracies, peptisator and temperature. First, it is corrected for the meniscus by adding the size of the meniscus to the hydrometer reading.

$$R_h = R'_h + meniscus$$

After this, corrections for zero point inaccuracies, peptisator and temperature are made. This is done by the reference reading, R_0, which is subtracted from R_h.

$$R_d = R_h - R_0$$

Also, correction must be made for the relative density, G_s. This is done by multiplying the corrected hydrometer reading with a factor found at:

$$k_{Gs} = \frac{1{,}65}{2{,}65} \cdot \frac{G_s}{G_s - 1}$$

If a large amount of remaining sample is left at the wash out, G_s must be found from the washed out part.

$$Y = R_d \cdot k_{Gs}$$

The corrected hydrometer reading Y indicates number of grams of soil per litre of slurry with a grain diameter less than the ball diameter d.

This correction factor also depends on whether the hydrometer has been calibrated in slurry in de-ionised water or in slurry in a 0.005 molar $Na_4P_2O_7$ solution, but the deviation is without relevance.

Calculation of weight percentage

The content in the slurry soil of grain sizes less than d is calculated in percentage of the full dry weight of the slurry soil.

$$P = \frac{Y}{W_s} \cdot 100\%$$

The weight percentage content of grain sizes less than d of the original soil sample equals

$$\frac{E}{100} \cdot P[\%],$$

where E is the screenings of the 0.063 mm sieve in percentage of the dry weight A of the original soil sample.

Calculation of grain size d

The grain diameter, d, can be found with a re-write of Stoke's law, equation 1. In the re-write, among other things, the relative density is entered instead of the actual density. The re-write becomes:

$$d = \sqrt{\frac{18\eta \cdot 100}{(G_s - d_0)g \cdot 60}} \cdot \sqrt{\frac{h}{t}}$$

Since alteration in peptisator and peptisator concentration only has an insignificant effect on η and d_0, Stoke's law can be simplified to

$$d = K \cdot \sqrt{\frac{h}{t}}$$

where K variates with G_s and temperature T.

K depending on G_s and T can be read on the laboratory scheme for hydrometer analysis, figure 10.

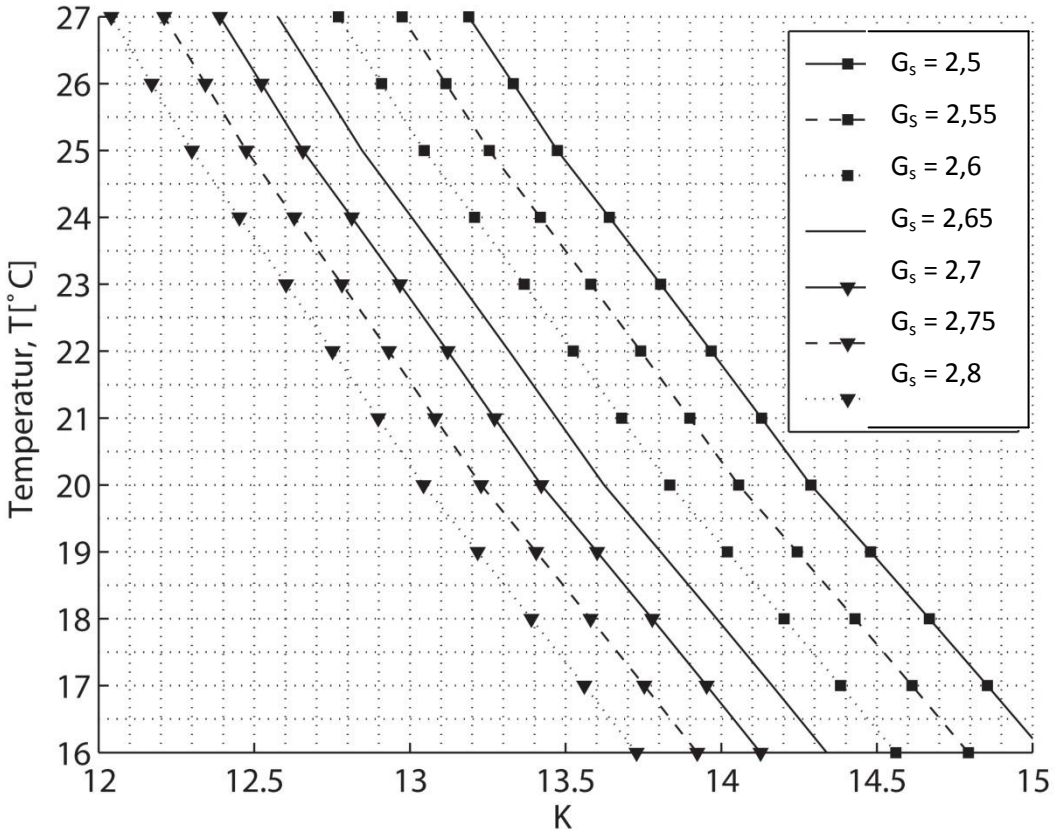

Figure 10: K-factor depending on temperature and the relative density.

The drop h can also be read at any time as function of hydrometer reading R_h corrected for the meniscus. The correction of the meniscus is done by adding the size of the meniscus measured in the reference reading to the hydrometer reading R'_h in question. This is done before the drop is read in the drop scheme. The most recent drop scheme can be found in the Geotechnical Engineering Laboratory at Aalborg University.

The grain diameter is, thereby, given with:

$$d(mm) = K \cdot 10^{-3} \sqrt{\frac{h(cm)}{t(\min)}}$$

Reporting

Corresponding values of weight percentages and grain sizes are put in the same coordinate system as the sieve curve in continuation of this. The recorded curve part is considered as the slurry curve.

Remarks

The stated drop times are only indicative. Readings of other times can be made as long as these are noted.

The measuring glass must not be exposed to shaking during the experiment.

The air temperature of the room must be constant as far as possible. It is important to prevent horizontal temperature gradients (sun, heating apparatus or an open window), which can cause convection currents.

The top side of the measuring glass with the slurry should at any non-used moment be covered up so as to avoid evaporation and dust settlement.

An uneven transition between the sieve curve and the slurry curve can be due to a defect in the wire cloth of the 0.063 mm sieve or that the wash out has been insufficient.

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Hydrometer analysis page 1/2

Case			Case no.
Examined	to	Lab. no.	Boring no.
Controlled d.	Approved d.	Level	Appendix no.

WATER CONTENT, full sample

Sample	No.	
Bowl	No.	
Bowl in drying cab.	dd h.	
Bowl out drying cab.	dd h.	
Bowl	g	
Bowl +*W*	g	
Bowl+ W_s	g	
W_w $(W-W_s)$	g	
W_s	g	
$w = \frac{W_w}{W_s}$		

HYDROMETER

Hydrometer	nr	
Cylinder glass	nr	
G_s	-	
Sieve size, wash out	mm	
Meniscus top side	-	
Meniscus bottom side	-	
E in % of A	%	
Peptisator	-	

WASH OUT REMNANTS FOR SIEVING

Sample	No.	
Bowl	No.	
Bowl	g	
Bowl+ W_{rest}	g	
W_{rest}	g	
$W_{0,063}$	g	

SAMPLE SIZES

Sample	no.	
Bowl	no.	
Bowl	g	
Bowl+W	g	
W	g	
W_s	g	

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Hydrometer analysis page2/2

Case			Case no.
Examined	to	Lab. no.	Boring no.
Controlled d.	Approved d.	Level	Appendix no.

HYDROMETER READINGS

Drop time m	0.25	0.5	1	2	Temp.	Temp. (ref)	R_0
Hydro.rea. 1							
Hydro.rea. 2							
Hydro.rea. 3							
Hydro.rea. 4							

Drop time m	2	4	8	30	90	240	480	1440
Time of reading								
Hydro.rea. (R'_h) g/l								
Temp. °C								
Corr. Hydro for meniscus (R_h) g/l								
Corr.fac. for temp. and pep. (R_0) g/l								
Corr. Hydro. (R_d) g/l								
Corr. G_s (k_{Gs}) -								
Hydro. Corr. (Y) g/l								
Screenings (P) %								
Screenings of A %								
Drop height (h) cm								
Coefficient (K) -								
Grain size (d) $K \cdot 10^{-3} \sqrt{\frac{h(cm)}{t(\min)}}$ mm								

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